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GB 2096402 A EP 0192349 A2 WO 87/01557 A1

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(54) Moulded circuit board

(57) A circuit board is formed by defining a pattern of metal conductors (40) on a metal foil (10). The metal foil is then inserted into a mould (50) and a thermoplastic (60) is injected into the mould. After ejection from the mould the metal foil is removed to leave the conductors buried in and intimately contacted to the plastic. Optional features include forming the foil into a nonplanar shape and the inclusion of metal heat transfer studs and connectors.

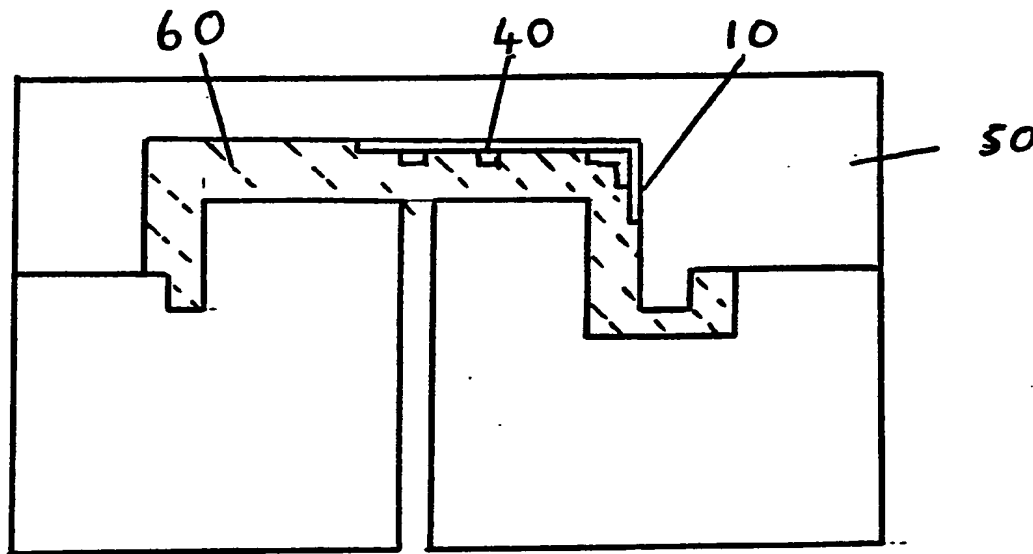
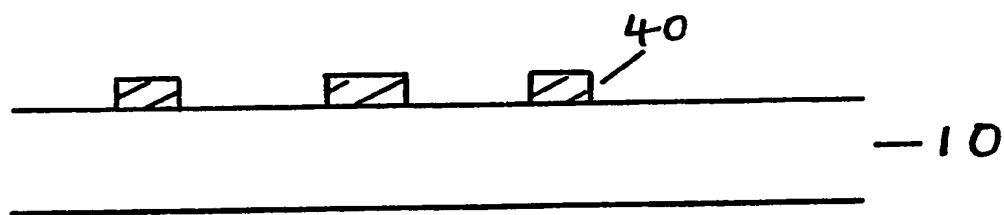
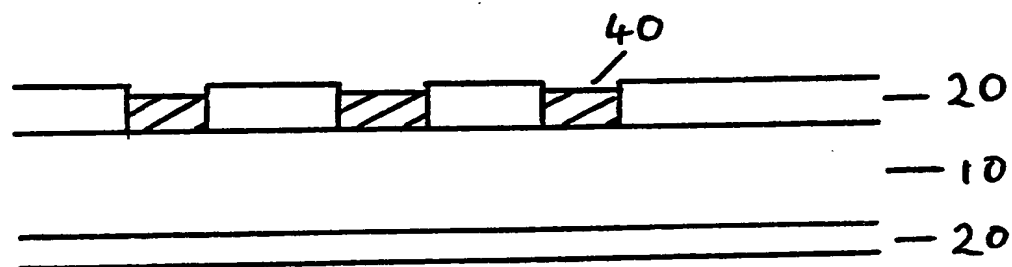
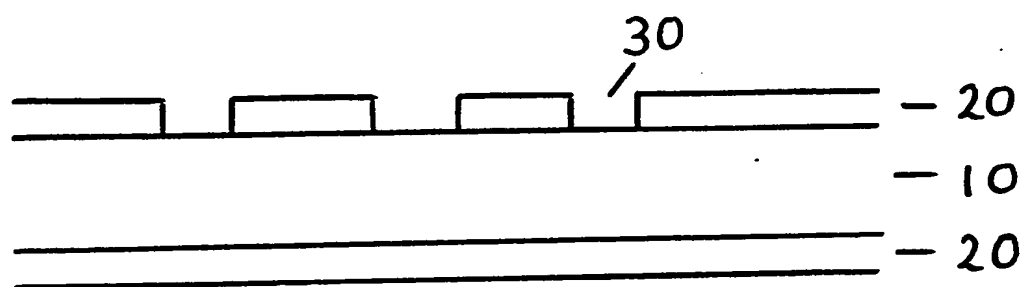
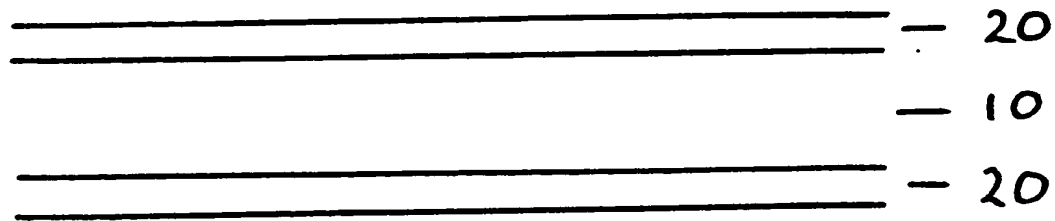


FIG 5

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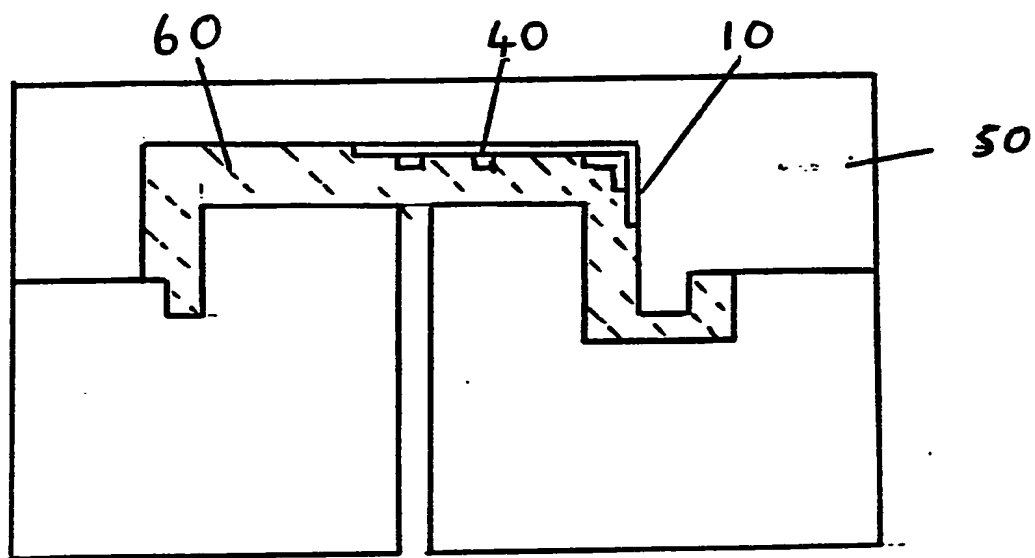


FIG 5

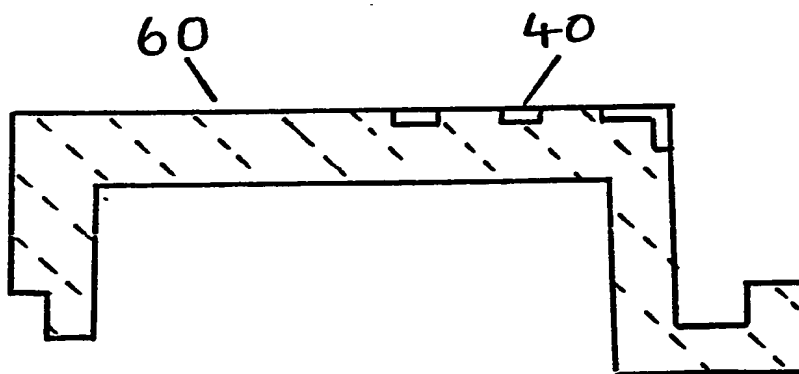


FIG 6

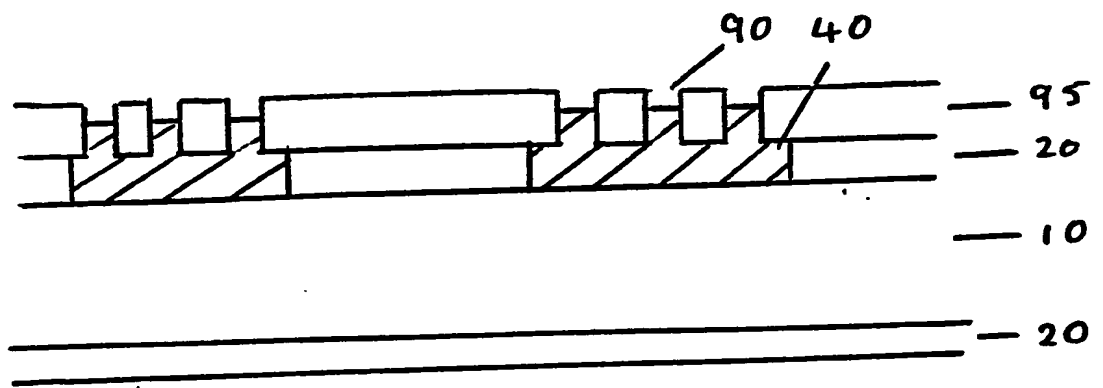


FIG 7

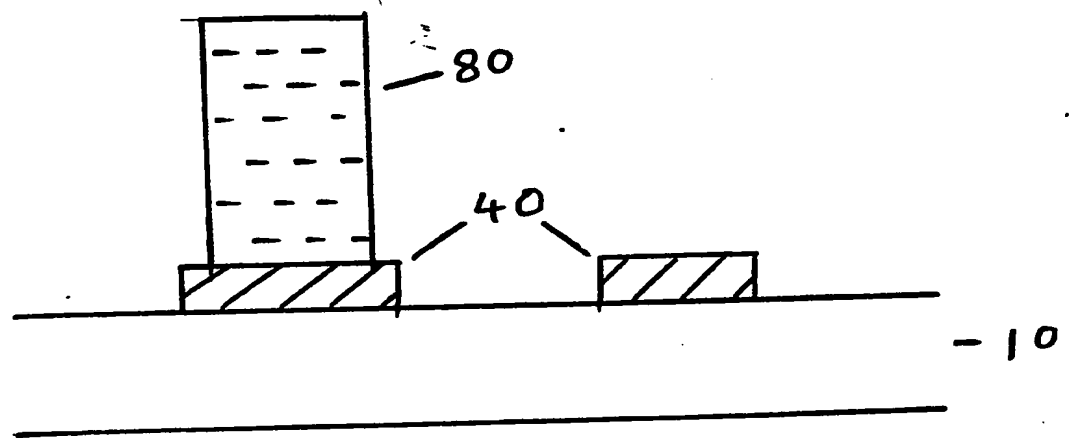


FIG 8

## MOULDED CIRCUIT BOARD

BACKGROUND

There have over the last few years been several disclosures relating to the possibilities of fabricating printed circuit boards by the use of moulding to form the insulating substrate. A key aspect of these methods is the ability to produce boards in three dimensions. Such techniques fall into two broad categories: those in which the tracking is attached at the same time as the part is moulded and those in which the conductive tracking is added after moulding. Examples of the former include the process described by Atkinson (WO8701557) and that described by Gregory (US4710419). In Atkinson's approach the tracks are fabricated from a conductive silver paste whilst Gregory's method uses instead plated copper tracks. Both these methods employ a thermoplastic backing sheet to carry the tracking and which is inserted into the mould prior to injection moulding with the tracks facing the walls of the mould so that the backing sheet subsequently becomes an integral part of the moulding. It is claimed by Gregory that this beneficially enables the part to be moulded into its final form and that no further processing is required.

In alternative methods described by Frisch (GB2171355A), Polichette (US3907621), Elarde (US4532152), Metler (Canadian 1075825) and Hagner (US4604678) and derivatives of these patents, the copper tracking is added after moulding. In the process known by the trade name Konec and licensed to Amoco a silver particulate tracking is glued to the premoulded part using a transfer type process.

Those processes involving a circuit pattern inserted into the mould on a thermoplastic carrier sheet have the disadvantage that the backing sheet can move around when it is placed in the hot mould and even hotter molten plastic enters into the mould.

It is an objective of the current invention to provide an improved copper conductor moulded circuit board with the tracks applied at the same time as the part is moulded. This will enable the use of virtually any thermoplastic whereas in the case of boards in which the copper tracking is added to the premoulded part the choice of plastic is limited to those materials that can easily be treated to accept copper plating. At the current time all of these have some substantial disadvantage when employed as an electrical circuit board.

A key feature of the disclosed method is the use of a sacrificial circuit carrier sheet. Such methods in themselves are not new and references can be traced back to Pritikin (US2692190, US2721822, US3135823, and US3181986). In these techniques Pritikin has demonstrated the use of both entirely sacrificial carrier sheets and also reusable sheets. This work has formed the basis for several subsequent applications such as that of Perstop (US3886022) in which a similar method is used to form a thin blank copper layer on an insulating plastic layer. A more or less identical approach to that of Pritikin has been proposed by Laakso et al (EP192349) as a method of metallizing polyimide. More recent work by Theron (EP213336) and Fukutome (Trans Inst Electron Inf Comm Eng (JAPAN) Vol572C-11 Pt4 April 89) have extended earlier proposals (US3039177) for the use of the technique to fabricate two sided boards. GB 2096402 and EP 258451 contain disclosures that are broadly similar to the earlier techniques. All these disclosures refer specifically to boards that are fully contained in a single plane. Bardett (US3039177) however discloses the use of a thermosetting material to form a single or double sided board bent into a multiplanar channel.

The current disclosure relates to a new form of the technology that possess attributes particularly attractive to the modern electronics industry. The insulating medium employed is one of the so called engineering thermoplastics, particularly those with high heat deflection temperatures. The use of a thermoplastic is

important in reducing the cycle time of the moulding to economic levels. Using a thermoplastic necessitates steps being taken to improve the adhesion of the conductor to the plastic and this is disclosed. The choice of a metal carrier enables the circuit to be formed into three dimensions rather than simply bent. A key option described here is to attach metal parts to the carrier sheet prior to moulding. These parts could be connected to the circuitry electrically in which case they could form part of say a connector or isolated from the circuitry to form a heat transfer stud.

#### DESCRIPTION OF THE INVENTION

According to this invention initially a combination of carrier sheet and the circuitry is formed by one of several processes and this combination is then modified by features to enhance the adhesion of the tracks to the plastic and if required the addition of metal parts to this combination. Finally, if required, the carrier sheet is formed into three dimensions, inserted into the mould and the thermoplastic is injected into the mould. After ejection from the mould the part is completed by removing the carrier foil by dissolution in an etching fluid.

According to this invention a metal foil is coated on both sides with a conventional dry film photoresist and a pattern of openings corresponding to the desired conductor pattern is developed in the photoresist on one side of the foil. A metal is then plated in the channels of the openings to a thickness sufficient to eventually form the main bulk of the conductors of the circuit board. The resist is then removed from the metal foil and the metal foil is then placed in the mould after, if desired, a mechanical forming step to obtain a non-planar conductor pattern. A plastic is then injected into the mould and this plastic subsequently forms the body of the circuit board with the conductors still attached to the carrier sheet, buried in the plastic. The side of the carrier sheet not carrying the conductors is exposed on one of the surfaces of the moulded part.

Finally the metal foil is dissolved in a fluid that attacks neither the plastic used nor the metal forming the conductors.

According to this invention an adhesion promotion layer may be incorporated just before the photoresist is removed. This may be by means of roughening the surface of the tracks or by adding a second layer of photoresist, developing a pattern of small holes in the resist over the tracks and then plating in the holes to form an array of metal columns. These columns may be plated to beyond the thickness of the resist to produce an array of mushroom shaped columns of metal which subsequently form an excellent mechanical key to the plastic. The resist layers are then removed and the process continues as previously described.

Still further according to this invention just before the foil is inserted into the mould metallic parts may be attached to the foil and inserted into the mould with the foil. This metallic part will then become an integral component of the finished article.

#### PREFERRED EMBODIMENT

The preferred embodiment will now be described with reference to the following diagrams.

Figure 1 shows the carrier sheet, after treatment, coated with photoresist

Figure 2 shows the photoresist after definition of the conductor track openings

Figure 3 shows the carrier foil after plating the copper tracks

Figure 4 shows the copper tracks and carrier sheet after removal of the photoresist



Figure 5 shows the carrier foil inserted into the mould and plastic injected into the mould

Figure 6 shows the final part after removal from the mould and etching of the carrier foil

Figure 7 shows the carrier sheet with a second layer of photoresist added and adhesion promoting columns of copper added.

Figure 8 shows the carrier sheet with a metal insert attached.

R1M  
An aluminium foil (10) about 100 microns thick but of any convenient thickness typically but not limited to the range 20 to 300 microns is treated with a zincating process ( for example Canning Bondall ) to enable the aluminium to be copper plated. A thin ( typically 1-2 micron ) layer of copper is plated from a non-acidic solution to enable the foil to be subsequently plated with copper from an acidic solution. The foil is then coated on both sides with a photoresist ( 20 ), for example Du Pont Riston 1010, but any suitable type and thickness would be acceptable. (see Figure 1) A pattern ( 30 ) is then formed in the resist on **one** side of the foil by exposing the resist to ultraviolet light through a photomask and then washing out the pattern as described in the manufacturer's literature and as is well known in the industry. (see Figure 2)

Copper (40) is then electroplated in the channels defined in the resist to a thickness of about 20 microns but which could be of any suitable thickness from 3 microns to 200 microns as determined by the thickness of the resist. This process is well known in the printed circuit board industry. (see Figure 3)

The photoresist is then removed using any of the fluids sold for this purpose, the particular choice has no significance for the invention. (see Figure 4)

The carrier sheet bearing the conductor pattern is then optionally subjected to a mechanical forming step to produce a non planar circuit and then placed in the mould such that the plain side of the carrier sheet is adjacent to the surface of the mould.

An optional step prior to placing the carrier sheet in the mould is to attach to the foil any metal parts such as connector pins or heat transfer studs ( 80 ). A suitable attachment method is ordinary tin lead solder, but a higher temperature solder may be preferred if the mould temperature is close to or above the melting temperature of the solder. (see Figure 8)

A suitable thermoplastic (60), typically but not limited to polyphenylene sulphide, is then injected into the mould<sup>(50)</sup>. After the part is ejected from the mould the part contains the aluminium foil on one exposed surface and the copper conductors on the other buried in and intimately bonded to the plastic. Any metal parts attached to the carrier sheet would also be held firmly in the plastic. (see Figure 5) Finally the various metal layers are removed by chemical dissolution. The thin copper layers can be etched in ferric chloride, the zinc coating in hydrochloric acid and the aluminium in sodium hydroxide. The strengths of the acids and alkalis are typically in the range 10% to 40% but are not limited to these values in any sense. (see figure 6)

Another optional enhancement to the process is to add a second layer of photoresist<sup>(45)</sup> just after the copper plating step, form in the second layer of the resist a matrix of holes or tracks, and to electroplate a matrix of metal columns on the conductors (90). If desired these columns can be plated above the thickness of the resist to form a mushroom shape. The resist is then removed and the process continues as before. These columns or tracks then act as a mechanical key to the plastic. *see figure 7*

It will be readily appreciated that there are a variety of methods for forming a suitable carrier sheet. For instance the foil could be plated over the entire area with the tracking metal and the conductor pattern etched into the added layer. Alternatively the carrier foil and the tracks could be of the same metal and a barrier layer plated between them as the first operation after developing the photoresist. Suitable metals are copper for the carrier foil and track and nickel, silver or gold for the barrier layer. Similarly although the choice of metals described here have practical application there are a wide variety of materials that could be used and the particular choice is not of significance to the invention.

The particular choice of thermoplastic may be selected from a wide range that could include nylon 4/6, nylon 6/6, polyester PET, polyester PBT, polyester PCT, polyphenylene sulphide, polyetherimide, polyethersulphone, polysulphone, polyarylsulphone, polyetherketone, polyetheretherketone, or one of the liquid crystal polymers such as ICI's SRP or Hoechst's Vectra. For strength these would generally contain glass fibre reinforcement. The choice of plastic does not form a limitation on the process described.

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CLAIMS

- 1 A process for forming a circuit board consisting of the steps of
  - a) forming a pattern of conductors out of metal on one surface of a metal carrier foil
  - b) placing the foil in a mould such the pattern of conductors faces away from the surface of the mould, and injecting a thermoplastic into the mould.
  - c) removing the part from the mould
  - d) removing the carrier foil by chemical dissolution to leave the conductors electrically isolated and buried in the plastic.
- 2 A process according to claim 1 in which the circuit pattern is formed from a different metal to the carrier foil
- 3 A process according to claim 1 in which the metal forming the conductors and the metal forming the carrier foil are the same material. In this case a barrier layer is formed between the conductors and the carrier foil
- 4 A process according to claim 2 or claim 3 in which a matrix of metal columns or tracks is formed on the conductors prior to insertion in the mould in order to provide a mechanical bond between the tracks and the thermoplastic during moulding

- 5 A process according to claims 2 3 or 4 in which the foil is formed into a non planar shape prior to insertion into the mould
- 6 A process according to claims 2, 3, 4, or 5 in which a metal part is attached to the foil prior to insertion into the mould. This metal part may be either electrically isolated from the conductors or electrically connected to the conductors according to the desired function of the part.
- 7 Any process substantially in accordance with the prece ding claims
- 8 A circuit board formed by the process described in the prece ding claims

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